that the phenomenon is independent of diffusion. The colloidal septum is capable of hydrating itself to a higher degree in contact with pure water than in contact with alkaline solution. Colloidal septa, swollen in consequence of contact with dilute acid or alkali, appear to acquire increased sensibility to osmose, in consequence of their unusually high degree of hydration.

III. "On some new Phenomena of Residuary Charge, and the Law of Exploding Distance of Electrical Accumulation on Coated Glass." By Sir W. Snow Harris, F.R.S. Received May 17, 1861.

(Abstract.)

A main object of this paper is to prove that residuary charge in the Leyden jar, subsequent to explosive discharge through an external interrupted circuit, as in the case of discharge by a Lane's electrometer, is not the result of a spreading of the charge upon the uncoated part of the glass, or of penetration within its substance, but arises from an undischarged portion of the accumulation left as it were behind, and still existing in precisely the same way and under the same conditions as the original charge.

The author introduces his subject with sundry observations on Lane's discharging electrometer, and the law of explosive discharge, and adverts to the fact recorded by Nicholson in the Royal Society's Transactions for 1789, that "although in moderate charges the exploding distance appears exactly, or very nearly, proportionate to the charge itself, yet for high intensity, the distance to which the charge is carried exceeds that proportion:" this the author finds to be the case generally, and quotes an experimental example showing the amount of deviation from Lane's law in that particular instance. He further shows, that in order to obtain explosive discharges at the increased distances agreeing with the calculated number of measures, the distances must be slightly increased by certain small quantities.

The probable sources of these differences are now adverted to, and the common objections to Lane's discharging electrometer considered. A new and improved form of this instrument is figured and described. One of its principal advantages is a means of changing the exploding points of the discharging balls, which are moveable on

axial centres, so as to bring a new point of the circumference into play, should abrasion or any other defect arise in the existing exploding point. The author endeavours to show that the apparent irregularities so frequently observed in the striking distance of a charged electrical jar, do not arise from any defect in the quantity measure, or in the exploding electrometer when properly constructed, but are altogether dependent on some peculiar conditions of electrical accumulation on coated glass.

One remarkable peculiarity of the electrical jar, is a disposition to retain a portion of the charge notwithstanding explosive discharge has occurred through a discharging circuit; we do not discharge the whole accumulation; a portion is, as it were, left behind. The fact itself is undisputed, but the cause or theoretical explanation does not appear to have been very clearly comprehended.

The author here introduces some interesting quotations from certain unpublished manuscripts of Mr. Cavendish, who investigated so long since as the years 1771 and 1772, what he terms the "charges of plate glass and other electrical substances coated in the manner of Leyden phials." Mr. Cavendish found his experimental inquiries greatly embarrassed by the "spreading of the electricity" on the glass; it is, he says, faster on some kinds of glass than on others; besides the slow and gradual spreading, he observed an instantaneous spreading, visible in the dark, and extending to about ·07 of an inch beyond the edge of the coating upon glass ·2 of an inch thick, and about ·09 upon glass $\frac{1}{15}$th of an inch thick. Another source of inconvenience, observes Mr. Cavendish, arises from a certain amount of penetration of the charge into the substance of the glass itself, equal to about $\frac{7}{16}$ths of its thickness; the space, he says, within which the charge cannot penetrate is not above $\frac{1}{8}$th of the thickness, from which he concludes that the charge of a coated electric will be different in cases in which this penetration of the charge into the substance of the glass varies, and infers that different electrics are susceptible of different degrees of charge. He examined plates of glass of various kinds, as also of gum-lac, rosin, bees-wax, &c., and found the capacity of these substances for electrical charge different—phenomena recently explained by Faraday's fine discovery of Specific Inductive Capacity.

This last celebrated philosopher also recognizes the penetration or

infiltration of electrical charge within the substance of coated and charged electrics, and attributes it to a certain amount of conducting power in the electrical substance. All substances, he infers, are conductors of electricity in a greater or less degree, and thus admit of infiltration of charge through their substance. In the case of charged electrics, the infiltrated electricity subsequently returns upon its path, and hence residuary charge.

The author has no disposition to question the experimental results arrived at by either of these eminent men, but is of opinion that they apply to a different case of electrical force than that of secondary and immediate discharge, supervening upon a primary discharge of an electrical jar, through an external explosive circuit, which he thinks can neither be referred to any previous spreading of the charge upon the glass, or to any penetration of it into its substance, or to return action as described by Faraday. He has found that of 100 measures of accumulated charge on a jar with imperfect conducting coatings, no less than 75 measures, or three-fourths nearly of the whole accumulation, has been left behind after explosive discharge. In a jar coated with water, full 14 measures out of 100, or about one-seventh, was left undischarged. He thinks it difficult to reconcile such an amount of residuary charge as this, with any spreading of the electricity on the glass, or any possible amount of penetration into its substance.

Although the deductions of Cavendish and Faraday may not be found to apply as solutions of the interesting problem of residuary charge, they still find their application in other cases, as in the case of the facts noticed by Nicholson already detailed. The intensity of explosive discharge may apparently become increased by a penetration of the exploding electricity into the air separating the balls of the discharging electrometer, in which case the measured distances of discharge, according to Cavendish, would, for given measured quantities of electricity, continually decrease, and discharge at the measured distances between the exploding balls would appear to happen prematurely. It is now shown by reference to a Table of experimental results, that at distances 1, 2, 3, 4, taken in tenths of an inch, with quantities of measured charge also as 1, 2, 3, 4, the actual distances of explosion are nearly as ·1, ·214, ·325, ·445. The author hence infers that, supposing the penetration of the first

measures very small and not of much value, the penetration of the succeeding measures may be taken as ·014, ·025, ·045, that is ·007, ·0125, ·0225 upon each of the opposed exploding points, taking the surfaces of the exploding balls as curvilinear coatings to the intervening air.

If any considerable spreading of the charge upon the uncoated glass should arise, that, as remarked by Cavendish, would be equivalent to an increase of the coating, and hence the tension due to a given quantity of charge would be less. The effect would be greater on the first measured quantity than on succeeding quantities; hence for explosion at a first distance, an additional two or three measures might be required, which, as the spread upon the glass became satisfied, might not be requisite in the same proportion upon succeeding measured distances, in which case discharge would ensue with a less number of measures than calculation determines according to Lane's law, making it appear as if, according to Nicholson, "the intensity ran before the quantity."

Both Franklin and Nicholson have taken a sound practical and theoretical view of electrical accumulation on coated glass, which the author conceives to depend on a play of opposite electrical forces, either directly through the glass intermediate between the coatings, or through the medium of an external circuit, or both. He considers the terms "free" and "compensated," or "latent" electricity, perfectly admissible when correctly applied and limited by sound definition. All the accumulated charge, up to the exploding point, is evidently not sensible to the electrometer, and he thinks it convenient to distinguish between that portion of the charge of which the electrometer directly says nothing, and that portion to which its indications are more immediately referable, more especially as these two, or conjugate portions, have important relations to each other. Thus a double measured charge has twice the amount of free charge; and the free charge, as estimated by attractive force, is as the square of the accumulation. When the free charge explodes, the whole accumulation, or nearly all, goes with it, at least in common cases of metallic coated glass, and according to Nicholson carries it through distances proportionate to the charge itself: the terms "free" and "latent" electricity, or, as the French have it, "electricité dissimulée," may not be exact or admissible, if meant to imply a difference in kind

or mode of action of electrical force, but they are by no means objectionable when denoting different amounts of the same force in this or that direction.

In considering the nature of electrical accumulation on coated electrics and the law of explosive discharge, we have to deal with a simple question of physical force taken in the abstract, and not with a theoretical electric fluid or fluids of high elasticity, subject to expansion or contraction, changes in thickness of stratum, tension, density, and the like. The terms "tension" and "intensity," so commonly applied to designate degrees of electrical force, are convenient and not inappropriate terms when legitimately applied and limited by definition. The term *intensity* is well adapted to express the attractive force of the charge in the direction of the electrometer, and which, in continually *increasing* according to a known law, terminates in explosion. The intensity or attractive force varies with the square of the charge. The term "tension" is more especially applicable to the constrained state of the dialectric particles sustaining the induction necessary to the charge, and is equivalent to the reactive force of the particles in an interrupted circuit of discharge to break down or reverse the polarized state of the dialectric medium impeding discharge, as between the exploding balls of the Lane's discharger: this is as the quantity of charge directly. In employing these terms, the author has not the least view to any specific changes in the quality or condition of the accumulated electricity, as relating to density, elasticity, and such like. Whether the tension and intensity of a charge, as evidenced by the electrometer, be great or little, he conceives that the nature of the force and its mode of operation remains the same. Viewing the process of electrical accumulation and discharge in the Leyden jar as the result of certain powers or forces operating either immediately through the glass or through an external circuit, or both, we may readily imagine that at the critical point at which the forces in the two directions become balanced, and at which point the equilibrium of charge is, at it were, overset on the side of the exterior circuit, then it is that residual charge ensues, either by a momentary revulsion of force between the coatings in the direction of the intervening glass, frequently causing fracture, or otherwise by a retention of some of the charge in that direction at the instant of explosion. Some instructive and important experiments by Mr. T. Howldy are here quoted in support of this conclusion, from the

pages of the 'Philosophical Magazine' for the year 1815. A ruptured jar had the coatings removed from around the perforated part, so as to admit of the jar receiving a given amount of charge. When explosive discharge took place in the usual way, a spark was observed to pass at the same instant between the coatings through the perforation in the glass, evidently showing an exertion of force in that direction. This spark is entirely independent of the discharge in the circuit, the force of which remains the same as if no such perforation existed, as Priestley and other electricians, and Mr. Howldy himself, have fully demonstrated.

Considering the question of residual charge as bearing materially on our views of the nature of electrical force, the author seeks to investigate, by new forms and kinds of experiment, the relation of the residual quantity to the whole charge, whether accumulated on glass coated with very perfect conductors such as the metals, or otherwise with less perfect conductors, as water, or with imperfect conductors, such as paper, linen and the like. The instruments employed are now enumerated and commented on, and their experimental arrangement figured and described. They consist of the electrical or Leyden jar; Lane's improved electrometer; the hydrostatic electrometer as recently perfected; the thermo-electrometer; quantity or unit-measure; and battery charger and discharger. The following is the course which the author pursued in his inquiries, through the medium of these instruments.

The quantity of charge being given, its intensity is measured by the hydrostatic electrometer in terms of attractive force at a constant distance, suppose at distance 1 inch. This is first noted: the jar is now discharged through its exploding distance by completing the circuit through the Lane's discharger. The hydrostatic electrometer, being now made perfectly neutral, is again brought into connexion with the inner coating of the jar. The intensity or attractive force of the residuary or remaining charge is now noted, but as this force is necessarily small, it is taken with the attracting plates at a diminished distance from ·1 to ·3 of an inch or more, as the case may require, and subsequently reduced to the standard distance of one inch, taking the force to vary, as demonstrable by the electrometer, as $\frac{1}{D^2}$. This being determined, the relative quantities of electricity in the full charge and the residual charge will be as the square roots

of the respective attractive forces or intensities; the total force, as also demonstrable by the instrument, being as the square of the accumulation. Let, for example, the quantity of charge communicated to the jar be 100 measures, and the attractive force, or intensity at distance one inch, be 144 degrees, and suppose intensity of residual force at the same distance $= \cdot 08$. In this case we have the simple proportion 100 measures : x measures : : $\sqrt{144} : \sqrt{\cdot 08} :: 12 : \cdot 283$ and quantity of residual electricity $= \frac{100 \times \cdot 283}{12} = 2\cdot 35$ measures nearly; so that of the original 100 measures of charge communicated to the jar, rather more than $\frac{1}{40}$th remains undischarged in this case.

The author here offers some explanatory observations on the relative dimensions and extent of coating of the unit of measure and the relative value of the measures quoted, and he thinks if electricians would agree to recognize a standard instrument of this description, it would be attended with very considerable advantage, as in the case of other standard instruments. The unit of measure he employs exposes about 9 square inches of coating; it is about 4 inches long, $\cdot 8$ of an inch in diameter, and $\frac{1}{20}$th of an inch thick; distance of exploding balls $\cdot 05$ of an inch. Similar observations were applied to the thermo-electrometer, the ball of which is 4 inches in diameter, and has a wire of platinum through it of $\cdot 01$ of an inch in diameter. The dimensions of the attracting discs of the hydrostatic electrometer are also noted, which in these experiments were 4 inches in diameter; the suspended disc weighs 82 grains. The discs are carefully gilded; 5 degrees of the arc of measure represents a force of 1 grain, that is to say, a weight of 1 grain added to either side moves the index 5 degrees of the scale. Having offered these preliminary remarks, the author proceeds to the following experiments:—

Experiment 1.—Variable charges, amounting to 50, 100, 150 measures, were successively accumulated on different jars, exposing from two to six square feet of coating, and the residual charges due to each noted; these were found to be as the total charge. Thus the residual charge for 100 measures was in every case double that for 50 measures.

In a succeeding Table are noted—measured charge; exploding distance; intensity at distance 1 inch; residual measures and thermo-electric effect of discharge. It appears by this Table that residual

charge is as the total charge; exploding distances, as the quantity or very nearly; intensities and thermo-electric effect of discharge as square of the quantity or number of measure accumulated.

The author finds that for every metal-coated jar, whether large or small, of thick or thin glass, exposing from 1·5 to 6 feet of coating, the residual charge or quantity left undischarged, varies between the limits of $\frac{1}{30}$th and $\frac{1}{50}$th of the total charge.

Experiment 2 investigates the effect of thickness of glass. Two jars, exposing 2·5 square feet of coating, were employed, their relative thickness being as 1 : 2, that is, $\frac{3}{20}$ths and $\frac{6}{20}$ths of an inch; 100 measures were accumulated and discharged at their respective exploding distances. The following results appeared:—exploding distance directly as thickness of glass; intensity or attractive force in direction of electrometer as square of the thickness; residuary charge in each case the same, being about $\frac{1}{45}$th part of the total charge; thermo-electric effect of discharge very nearly the same; so that whether discharged from thick glass or thin, under intensities of very different degrees the same quantity of electricity produces the same effect. The intensities in this case were as 4 : 1, yet the thermo-electric effect did not differ more than one or two degrees, one being 12°, the other 13°. The author finds, by numerous experiments on a series of jars, that the intensity indication has no influence on the force of discharge, the quantity discharged being the same. In a series of jars of different magnitudes, and in which the intensity of a given charge of 100 measures varied between the limits of 100 and 1000 degrees, there did not appear a difference of more than a few degrees amongst the whole; the effects varied between 8 and 11 degrees. Some little difference will generally arise in favour of electricity accumulated on a small area of coated glass; in consequence of the greater facility of discharge the accumulation has greater freedom of operation through the external circuit, as is shown by its greater effect on the electrometer.

A celebrated electrician, the late Mr. Brooke of Norwich, in a conference with Cuthbertson about the year 1800, stated that a Leyden jar coated with strips of metal $\frac{3}{4}$ths of an inch wide, leaving intervals of the same width between the strips, was equally efficient as a full coating in the ordinary way. Two equal and similar jars, about 1 foot in diameter and 19 inches high, were prepared accordingly; one fully coated to about 4 square feet, the other coated in strips

to about 3·5 square feet. The author, although doubting this statement in all its generality, still considered an investigation of it, more especially coming from such men as Brooke and Cuthbertson, desirable, and as being calculated to throw further light on the phenomena of the Leyden jar.

A few preliminary experiments seemed to accord with Mr. Brooke's view; the exploding distance of the two jars with a given charge did not appear extremely different. The accumulated electricity spread upon the glass between the strips of metal, and thus enabled the partially coated jar to receive a larger accumulation, upon the principle stated by Cavendish, than was really due to its extent of actual coating. Mr. Brooke, in the then state of practical electricity, might have been therefore easily led to imagine that a partial coating such as he describes was sufficient. It is, however, shown in this paper that the cases of the two jars are widely different. As the spread of the electricity becomes satisfied, a less charge is required for explosion, and the tension of a given quantity increases. The following are the results of experiments with 100 measures similar to the preceding:—

Full coating.

Exploding distance	·15	Intensity 100° at 1 inch.
Residual measures	2·45	Therm. electric effect 8°.

Partial coating.

Mean exploding distance..	·25	Intensity 160°.
Residual measures	4·97	Therm. electric effect 3·5°.

It is evident the two forms of coating are not equally efficient, the heating effect of discharge not being half as great in the partially coated jar, whilst the residual charge is twice as great. The experiment so far shows the spread of electricity on the uncoated glass to be a source of absorption of charge to a greater or less extent, and goes far to confirm the views of Mr. Cavendish, relative to the spreading of electricity on glass.

The phenomena of metal-coated jars having been so far examined, a similar course of experiment is followed with jars coated with less perfect conductors, commencing with water coatings. For this purpose a jar exposing nearly 5 square feet of coating was prepared with metal coating, and the results of a charge of 100 measures determined

and noted as before; the metal coating being removed, the same jar had an equal extent of water applied to its opposite surface coating. The method of effecting this is described. The author states that it was so perfect as to shield the experiment from all interference of vapour from the water surface, so that the jar completely retained the charge without any dissipation, and in no sense differed in this respect from a metal-coated jar.

The results of this experiment are not a little remarkable. The exploding distance of the 100 measures, whether with the metal or with the water coating, did not materially differ, except in apparent force, being for the metal ·22, for the water ·2. The exploding spark from the water coating, instead of the sharp ringing sound attendant on the exploding spark from the metal coating, is weak and subdued, and is often like the sound of fired damp gunpowder. The intensity or attractive force is also in each case alike, or very nearly; being for the metal coating 144°, for the water 142°. The residuary charges differed considerably, being for the metal coating about 2·25 measures, or about $\frac{1}{45}$th part of the total charge; for the water coating 14·5 measures, or about the $\frac{1}{7}$th of the total charge. The residuary charge with a water coating is more than six times as great as with a metal coating. The thermo-electric effect with the metal coating was 10°, with the water coating nothing; 200 measures, or double the charge, had no effect on the thermo-electrometer.

In this experiment it does not appear requisite that both the coatings should be water; one coating may be metal, as in the first forms of the electrical jar. The author could not, at least, discover any material difference in the results, and concludes that if the first forms of the electrical jar with an internal coating of water had been continued, we should have had but small experience of the effects of artificial electrical discharge on metallic wires.

Imperfect conducting substances employed as coatings to the electrical jar have very similar but very exaggerated effects. With coatings of paper we have a striking example of retention of charge. A jar exposing 5·5 feet of coated glass, first coated with metal and subsequently with paper, gave the following results under a charge of 100 measures.

Exploding distances, as in the former case, nearly the same, being ·23 and ·25; attractive forces or intensity also nearly the same,

being 158° and 160°; residual measures with the metal coating 2·5 measures, or about the $\frac{1}{40}$th of the total charge; with paper coating, in some experiments 80 measures, or about $\frac{8}{10}$ths of the total charge, so that the residual charges with metal and paper are as 1 : 32. Thermo-electric effect for metal coating 8°, for paper coating nothing. It appears from these and similar experiments, that the interposition of imperfect conductors between the coating and the glass of the Leyden jar must necessarily impair its efficiency, and change its electrical indications, especially when of any considerable thickness. Three turns of common linen interposed between the outer coating and the glass reduced the force of discharge from 11° to 6°, nearly one-half, whilst the residuary or retention of charge is considerably increased: this question, as bearing in some degree on the retention of charge by the electric cable, may not be undeserving of further investigation.

IV. "On the Bromide of Carbon." By ARTHUR C. W. LENNOX, Esq. Communicated by Dr. HOFMANN. Received May 24, 1861.

The compounds of carbon with bromine have as yet received but limited attention. The tetrabromide of carbon, CBr_4, of the methyl-series is altogether unknown. Kolbe failed in obtaining this compound by submitting disulphide of carbon at a high temperature to the action of bromine, and I learn from Dr. Hofmann that the action of pentabromide of antimony on the disulphide gives no better result.

The bromide of carbon, C_2Br_4, has been obtained by Löwig*, who procured this substance by the action of bromine on alcohol or on ether, when it is formed according to the equations—

$$C_2H_6O + 4Br_2 = C_2Br_4 + 4HBr + H_2O.$$

$$C_4H_{10}O + 8Br_2 = 2C_2Br_4 + 8HBr + H_2O.$$

These processes appear, however, to be attended with difficulties; at all events, Völckel†, who repeated Löwig's experiments, failed in obtaining the substance described by that chemist.

A simpler method for obtaining this bromide of carbon appeared to present itself in the perfect substitution of bromine for the hydrogen in olefiant gas.

* Annalen der Chemie und Pharmacie, iii. 292. † Ibid. xli. 119.